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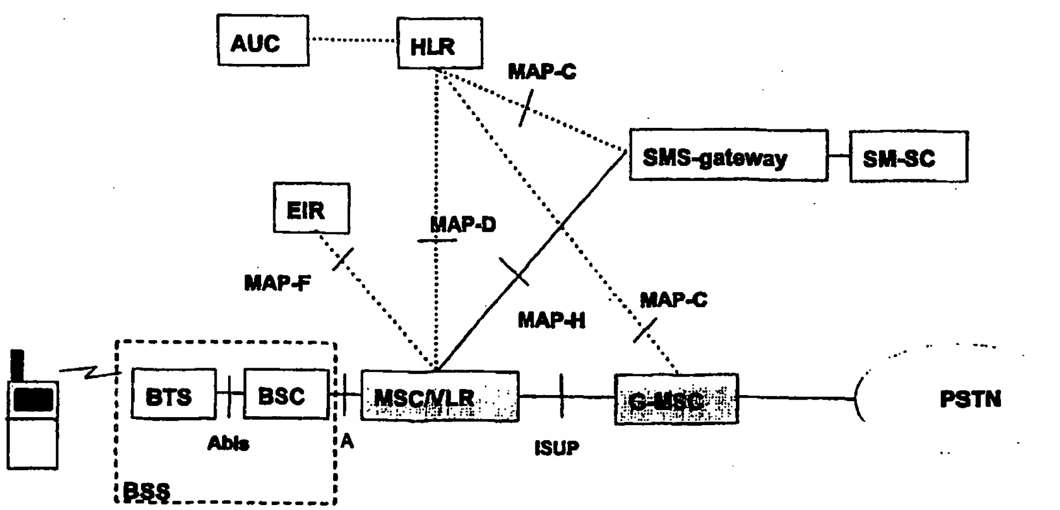

(57) Abstract

A network (GSM/GPRS) with functionality which is related to distribution of keys for authorisation, authentication and ciphering, subcriber information handling and CDR generation. The functionality is combined with the Internet protocol for transporting data and handling macro mobility to form an efficient as well as secure core network for mobile users.

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A (GSM–GPRS) NETWORK WITH INTERNET PROTOCOL COMBINED FUNCTIONALITY

The present invention relates to a network (GSM/GPRS)with functionality which is related to distribution or keys for authorisation, authentication and ciphering, subscriber information handling and CDR generation.

Since GSM (Global System for Mobile communication) was introduced in the Nordic countries in 1992, penetration has reached as high as 40 % - and is still increasing rapidly. However, this also means that large investments have been made in this system during those years. GSM is primarily a system for speech communication, which makes up 98 % of the total traffic. Data services exist, but are slow, inefficient and expensive since they are run on circuit switched connections.

In the year 2000, GSM will be enhanced with a general packet data service (GPRS), which uses the same radio access as GSM together with a new core network, based on IP. A maximum of about 150 kbps can be delivered, but the actual bandwidth will be significantly lower due to the presence of other users and the quality of the radio connection. Databases and servers containing subscriber data, equipment data, short message handling, etc. already in operation for the GSM system will be reused for GPRS.

Two years later, in 2002, UMTS (Universal Mobile Telecommunication System) will be taken into operation, delivering up to 2 Mbit/s over radio with full mobility. Contrary to GPRS, the UMTS radio access network will be built from scratch and existing core networks will be modified and reused to a large extent. For the initial phase of UMTS, the GPRS and GSM core networks are the most

interesting candidates because of their capabilities to handle mobile terminal and users.

UMTS will support mixed services, which means everything from Internet access to multimedia conferencing. Judging from how fixed Internet access presently is booming, one is tempted to believe that mobile Internet access will become equally popular. In addition, taking into account the development of IP telephony during the last year and the fact that video standards like H.323 [H.323] are being developed for IP networks, it is quite possible that an IP based network is the most future proof solution for UMTS. When constructing public mobile networks, one has to keep in mind that radio resources are scarce and that these networks are expensive to operate, and hence, it is necessary for the operator to have the means to charge the users for services that they use. In the near future, it is doubtful that this requirement can be fulfilled by (Mobile)IP networks. Operators, who have large investments in GSM and GPRS systems, could, however, reuse parts of those to complement the shortcomings of IP networks.

GSM and its future packet data service, GPRS, has an advanced system for

- authorisation and authentication of users/terminals, including key distribution
- ciphering over radio, including key distribution
- subscriber information handling
- CDR generation

through the VLR functionality in the MSC and the SGSN respectively and through the HLR and as well as other data bases.

The GPRS backbone is, however, not optimal because of its many successive protocol layers, which results in long delays and large overhead.

The Internet Protocol is simple, flexible and optimized for transporting data through networks. Enhanced with MobileIP for handling mobility, it could be used as a core network for mobile systems, i.e. the mobile user could get direct access to the Internet without passing through an additional network, like GPRS backbone. However, IP lacks support for subscriber handling and charging. Authentication and encryption is supported to ensure integrity and confidentiality but the key distribution, which is not standardized, is still a problem. The invention offers a solution of the security problem and form an efficient as well as secure core network for mobile users.

The solution to the problem is described in the claims.

UMTS is presently being standardardized and its core network will, in an initial phase, be based on the GPRS core network.

Advantages to the invention is that is possibly to use the fixed network in a more efficient way, when the GPRS backbone, in a later stage, is replaced by a purer IP network for transporting user data under the condition that the security issues are solved.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 The basic GSM architecture.

Figure 2 Overview of the GPRS logical structure

Figure 3 The GPRS Protocol architecture. The GPRS backbone is shaded

Figure 4. General UMTS Architecture with the reference points currently identified in UMTS, March1998 [UMTS23.01].

Figure 5. Using IP for service transport end-to-end.

Figure 6. Scenario with Mobile IP support for intra UTRAN mobility and modified SGSN's to handle subscriber data etc.

Figure 7. Scenario with Mobile IP supporting roaming in foreign networks.

Figure 8. Evolution scenario for UMTS. The IWU-Gb and IWU-Gbu are taken from [umts23.20].

A glossary of the abbreviations used in this patent specification is set out below to facilitate an understanding of the present invention.

AN	Access Network
AUC	Authentication Center
BSS	Base Sub System
CN	Core Network
DHCP	Dynamic Host Control Protocol

ETSI	European Telecommunication Standardisation Institute
GGSN	Gateway GPRS Support Node
GPRS	General Packet Radio Service
GTP	GPRS Tunneling Protocol
GSM	Global System for Mobile communication
HA	Home Agent
HLR	Home Location Register
SP	Service Provider
IP	Internet Protocol
IWU	InterWorking Unit
MS	Mobile Station
MSC	Mobile Services Switching Center
MT	Mobile Termination
PLMN	Public Land Mobile Network
PSTN	Public Switched Telephone Network
QoS	Quality of Service
SGSN	Service GPRS Support Node
SIM	Subscriber Identity Module
SP	Service Provider
TCP	Transport Control Protocol
UDP	User Datagram Protocol
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
UTRAN	UMTS Terrestrial Radio Access Network
VLR	Visitor Location Register

UMTS, the third generation cellular system currently being specified by ETSI, is the first cellular system to be optimized for extensive use of data services mixed with speech. One solution is to use the IP protocol for the

transport of services across core and access networks. Using a MobileIP core network would allow roaming between the radio access networks in a rather straightforward way. However, radio resources are scarce and public cellular systems are expensive to operate, and hence, it is of great importance that the users can be properly charged for services that they use. In the near future, it is doubtful that this requirement can be fulfilled by (Mobile)IP networks. Instead, parts of GSM/GPRS could be reused to complement the functionality of IP networks.

In this description, a network scenario is presented where the UMTS core network is based on Mobile IPv6, which supports roaming and possibly also handover between UTRAN's. Since the GSM/GPRS system already has several key functions to handle mobile users, e.g. subscriber data, access control, keys for encryption over radio, accounting information, the GPRS SGSN node should be reused to handle the setup of lower layer communication, including authentication and check of subscriber profile etc. A successful lower layer setup should be required in order to obtain a MobileIP care-of address. The mechanisms for distributing authorization and encryption keys in GSM/GPRS can also be utilized for distributing keys for the IPsec protocol.

Examples, describing how MobileIP and part of the GPRS core network could operate with a UMTS radio access network are presented later on in the description. The following three sections will give a brief introduction to those parts of GSM, GPRS, UMTS and IP that are relevant for this study. These are followed by a short discussion on using IP end-to-end in mobile networks, before presenting the examples.

GSM

GSM is a digital cellular system, primarily designed and used for speech communication[gsm]. A few data services and a rich set of supplementary services are standardized. The GSM network is built up of BSS's (Base Sub System), MSC/VLR's (Mobile Services Switching Center/Visitor Location Register), HLR's and a few other data bases and service nodes as illustrated in figure 1. The BSS contains base stations and base station controllers. Each terminal is equipped with a subscriber identity modules (SIM), which is a smart card containing, among other things, the user identity.

The MSC is the heart of the GSM system. It's duty is to:

- perform switching
- detect new mobile terminals in its service area and perform authentication and authorization procedures with these terminals
- collect information about users from their HLR and store the information in the VLR
- register location updates and store them in the VLR
- assist when handover takes place between MSC's
- create records for charging

Frequently, the VLR is integrated in the MSC. The Gateway-MSC is an MSC with additional functionality to handle traffic to and from the fixed network. For incoming traffic the G-MSC asks the HLR for routing information to the current MSC of the user.

The MSC communicates with databases like the home location register (HLR) and the equipment identity register (EIR) via

an SS7 based signaling system called MAP (Mobile Application Part).

The HLR stores the identity and user data of all the subscribers belonging to the area of the related G-MSC. The IMSI (International Mobile Subscriber Number), the phone number, service profile etc. are permanently stored in the HLR. For routing of incoming traffic, the user's current VLR and forwarding information is stored temporarily. Authentication and ciphering keys, which are derived in the AUC (AUthentication Center) are also available from the HLR.

Authentication and authorization of the terminal takes place each time a connection is setup, i.e. for each call. The authentication procedure is based on the authentication algorithm, which is stored on the SIM card and in the AUC. The AUC picks a random number from which the algorithm creates the authentication key. The random number and the key are then passed on to the HLR and the VLR, which sends the random number to the mobile terminal. The SIM card uses the random number to produce the key, which is returned to the network via the terminal. A comparison of the key received from the terminal and the one originating from the AUC will tell if the terminal is the expected one. The same method is used for giving the terminal the encryption key, but a different algorithm is used. This has the advantage that the encryption key is never sent over radio where it could easily be picked up by anyone. These algorithms are known nowhere outside the home network. On the terminal side, the algorithms are embedded in the SIM card and are available neither to the terminal nor to the user.

GPRS

GPRS (General Packet Radio Service) [GSM 03.60] is a packet switched service which, to a large extent, is based on a combination of GSM infrastructure, IP technology and a set of new functionality. Figure 2 describes the overview of the GPRS logical architecture. The main advantage of GPRS is that the limited radio resource is used only when there is data to transmit. There are two kinds of support nodes in the backbone, SGSN's (Service GPRS Support Node) and GGSN's (Gateway GPRS Support Node).

The main functions of the SGSN are to:

- perform authentication and other procedures to let new terminals connect to its service area
- send/receive data packets to/from the GPRS mobile
- keep record of the mobile's location inside its service area
- route data packets from one GPRS operator to another
- produce charging data records for the charging and billing system

The SGSN communicates with the HLR, the EIR, the SMS center etc. via a GPRS version of MAP.

The main functions of the GGSN are to:

- route data packets from one GPRS operator to another
- route mobile terminated data packets to appropriate SGSN where the mobile is currently located
- act as a gateway between GPRS network and external data networks (IP, X.25, etc.)

- handle de/encapsulation of user data protocol packets when communicating with external data networks.
- produce charging data records for the charging and billing system

GPRS Tunneling Protocol, GTP[gprs09.60], which is a specific to GPRS, tunnels user data packets between SGSN's and GGSN's. This enables the network to support transmission of several packet data protocols, even if the protocol is not supported by all SGSN's. GTP also transports signaling data for mobility handling between the nodes. As illustrated in figure 3, GTP is placed on top of the transport IP and UDP layer in the protocol stack. By using a non-standard protocol to transport user data, it is probably more difficult for users to do anything harmful to the system. On the other hand, it makes it impossible to use standard IP tunneling mechanisms without special solutions for GTP. An example is future resource reservation protocols, which are likely to operate in combination with standard IP-in-IP tunneling.

UMTS

The UMTS system, which currently is under specification in ETSI, is based on a new UMTS Terrestrial Radio Access Network (UTRAN) and existing, but evolved, core networks (CN) such as IP, GSM/GPRS CN or ATM [umts23.01]. The interworking units (IWU) adapt the different CN's to the Iu interface if needed. The GRAN and the CN's may evolve independently of each other, while the IWU's follow the evolution of CN's and AN's to insure interconnection between these parts. For flexibility, the user equipment consists of

different modules of which one is a UMTS version of the GSM SIM card, the USIM. A general view of the logical modules and reference points is shown in figure 4.

The UTRAN will probably have an internal mobility management system, which means that, for routing, the CN only needs to keep track of in which UTRAN the mobile terminal is located. The CN will have to handle the subscriber information management, basic call handling, paging initiation, service feature analysis, security issues, charging, etc. Evolved versions of the GSM and GPRS CN's are foreseen for the initial phase of UMTS [umts23.20]. Primarily, the IWU will deal with translation of protocol messages and network parameters, in those cases where the protocols in the CN and in the UTRAN are different. If the CN does not support functionality required for a UMTS CN, the IWU could contain intelligence to enhance the CN. The choice of protocols over the Iu interface has not yet been made.

The Internet Protocol

The Internet Protocol, IP, is designed to route IP packets across networks and network boundaries in a flexible and efficient way. Because of its popularity, many services have been developed to run on top of the IP protocol. Today, it is not unusual to implement virtual IP networks within other networks based on e.g. ATM or IP, which creates extra security, but also additional overhead and processing time. The GPRS backbone is one example of such a network. Taking into account that UMTS will not be introduced until year 2002, we only consider IPv6 [ipv6] here.

MobileIPv6 [mobip] is designed to deal with "macro" mobility management, i.e. the movements of mobile nodes

between different IP subnets. Routing in the Internet is based on fixed IP addresses, which depends on the subnet, through which the terminal is connected to the Internet. When connected to a foreign network, the mobile node needs a temporary address using the prefix of the visited network, a care-of address, to be able to receive packets.

Briefly, MobileIPv6 works in the following way:

- When the mobile node arrives in a foreign subnet, it acquires a care-of address using the IPv6 address autoconfiguration.
- The mobile node registers its care-of address with a router in its home subnet which acts as the node's Home Agent (HA). The home agent uses proxy Neighbor Discovery to intercept the IPv6 packets addressed to the mobile node's home address. The packets are then tunneled to the mobile node's care-of address using IPv6 encapsulation. This means that the mobile node can always be addressed by its home address, independently of which subnet it is roaming in.
- When packets, which are tunneled from the home agent, arrive at the mobile node immediately sends a message, which includes its current care-of address, to the communicating node. After receiving such a packet, the communicating node will send packets directly to the care-of address. This way, MobileIPv6 inherently supports optimized routing, which minimizes the load on the home subnet. When changing care-of address, the mobile node sends its new care-of address to its home agent and all other nodes that it is communicating with.

Using IP for Service Transport Across Different Networks

Traditionally, telecom systems have been developed with one kind of transmission, for one or a few specific and well specified services which need support by the network. GSM is one example of these kind of systems where the time-to-market for new services is too long to be competitive.

UMTS should support mixed services, services provided by third-party, etc and new services must be easy and fast to implement. One possible solution is to use IP as a common format to deliver services end-to-end. This does not necessarily mean that the IP *routing* mechanisms have to be utilized in all the different networks. For example, the UTRAN has to manage micro mobility, which includes frequent and fast movements between base stations, which Mobile IP is not designed to handle. Instead, the IP layer could be provided a point-to-point connection between the IWU and the mobile terminal while the UTRAN handles the changing connections underneath.

The main advantages of this approach is that already today, an abundance of services and information is available on the Internet. Having direct Internet access from the mobile terminal would facilitate the convergence of fixed and mobile networks on a service level.

In figure 5, the end-to-end IP layer is mapped onto the UMTS architecture. The IWU would provide interworking between the lower layers of the core network and the access network.

GSM, IP and Broadband Radio Access - a Mix that Matches

As we have seen in previous sections, the UMTS UTRAN together with GSM/GPRS core networks would give us a system, which would handle mobile users excellently and provide high bandwidth connections over the radio interface. There is also support for the operator to profit from running such a network. However, neither GSM nor GPRS are designed for large volumes and the GPRS backbone is rather inefficient due to the large overhead.

On the other hand, IP is simple and flexible for transporting data through networks. Enhanced with MobileIP, which is optimized for roaming between subnets, it is an interesting UMTS core network candidate. Unfortunately, it's support for subscriber handling and charging is poor.

Let us therefore study how the different parts from IP, GPRS and UMTS could interwork to support mobility. First, we will study the case, which is illustrated in figure 6, where the terminal stays within its home IP network :

- The mobile terminal arrives at a new UTRAN and listens to the radio broadcast messages, which contain information about radio parameters, network and cell identity, etc. as well as information about available core networks, service providers, service capabilities etc.
- The mobile terminal sends a registration request including parameters such as identity, desired service provider etc.
- The UTRAN forwards the registration request to the SGSN, which processes it:

- The SGSN contacts the HLR of the mobile terminal to collect data to perform an authentication procedure.
- Once the terminal is authenticated and found to be allowed in the present UTRAN, all information over the radio interface can be encrypted. Encryption keys are obtained from the HLR. A random number is sent to the mobile which can calculate the key with an algorithm stored in the terminal. This way, the key is not sent over the radio interface.
- At this point, the terminal also gets registered in the UTRAN along with location data and radio specific information.
- Now, the terminal can start communicating over the IP layer. The terminal listens to router advertisement messages and solicit the nearest DHCP server [dhcp] to obtain a configuration parameters and a care-of-address. It is assumed that only stateful address configuration will be used, since it gives a better support for registration of the terminals than stateless. Logically, we include the IP functionality in the SGSN and call the entire unit SGSN' and the HLR records include the care-of address of the mobile terminal.
- The mobile terminal will then contact its home agent to register its new care-of address according to standard MobileIP.
- The home agent has to accept or reject the registration of a care-of address. Before making a decision, the home agent could contact the HLR (via a new interface) to obtain information that this terminal is properly registered. In addition, the keys needed for using the

IPsec authentication header and/or the encapsulation security payload [ipsec] could be obtained from the HLR. The mobile terminal can derive its keys from information on its USIM in the same way as in the GSM system.

- While the terminal is connected and transmits data, charging data records are produced by the SGSN'. Systems for billing and customer handling, already in operation for GSM, can easily be used also for UMTS.

In figure 7, the mobile terminal is roaming in a foreign network. The procedure for registering in that network is very similar to the home network case, the only difference being that the visited SGSN' contacts the HLR in the terminal's home network, either via the international SS7 network or by tunneling the MAP protocol messages through the Internet. The mobile terminal registers with the same home agent as before.

The ETSI group SMG12 works with UMTS architecture and evolution scenarios[umts23.30]. One idea for evolution is depicted in figure 8. The most straightforward way to implement UMTS with an already existing GPRS network is to attach the UTRAN to the Gb interface via the IWU-Gb. However, if the UTRAN will be based on IP, a new IP based interface, Gbu, should be opened up at the SGSN, requiring an IWU-Gbu. In this description we have gone one step further and transformed the SGSN into an IWU for a core network based directly on standard IP and MobileIP.

UMTS, the third generation cellular system which is currently being specified by ETSI, is the first one to be optimized for extensive use of data services mixed with speech. One solution is to use the IP protocol for the transport of services across core and access networks. Using a MobileIP core network would allow roaming between URAN's in a rather straightforward way. However, radio resources are scarce and public cellular systems are expensive to operate, and hence, it is of great importance that the users can be properly charged for the services they are using. In the near future, it is doubtful that this requirement can be fulfilled by (Mobile)IP networks. Instead, parts from GSM/GPRS could be reused to complement the functionality of IP networks.

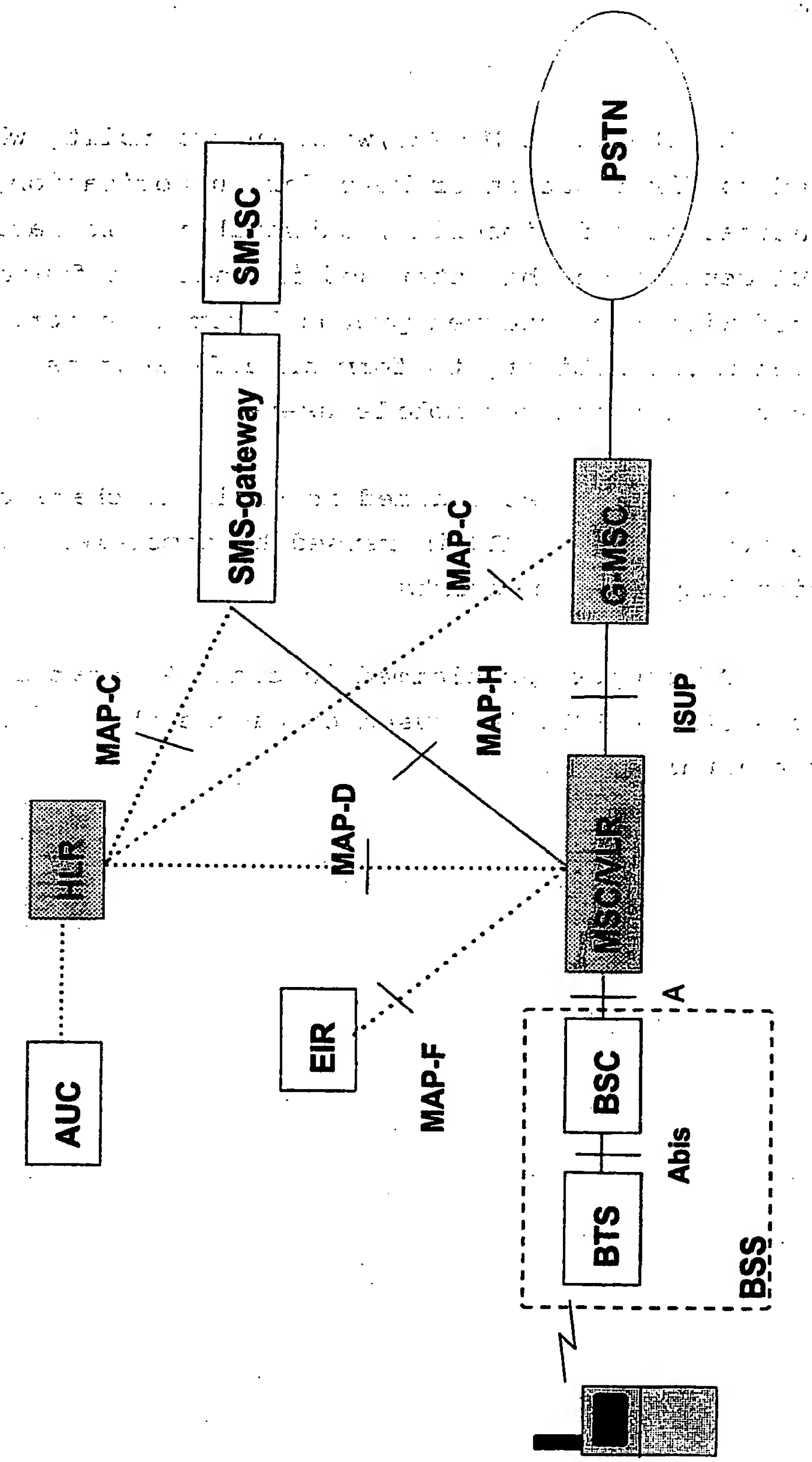
In this description, a network scenario is presented where the UMTS core network is based on Mobile IPv6, which supports roaming and possibly also handover between UTRAN's. Since the GSM/GPRS system already has several key functions to handle mobile users, e.g. subscriber data, access control, keys for encryption over radio, accounting information, the GPRS SGSN node should be reused to handle the setup of lower layer communication, including authentication and check of subscriber profile etc. A successful lower layer setup should be required in order to obtain a MobileIP care-of address. The mechanisms for distributing authorization and encryption keys in GSM/GPRS can also be utilized for distributing keys for the IPsec protocol.

CLAIMS

1 A network (GSM/GPRS)with functionality which is related to distribution or keys for authorisation, authentication and ciphering, subscriber information handling and CDR generation characterised in that the functionality is combined with the internet protocol for transporting data and handling macro mobility to form an efficient as well as secure core network for mobile users.

2 A network, as claimed in claim 1, characterised in that parts from GSM/GPRS is reused to complement the functionality of IP networks.

3 A network, as claimed in claim 2, characterised in that the GPRS - SGSN is reused to handle the setup of lower layer communication.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PSTN
G-MSC
MAP-C
MAP-C
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MAP-D
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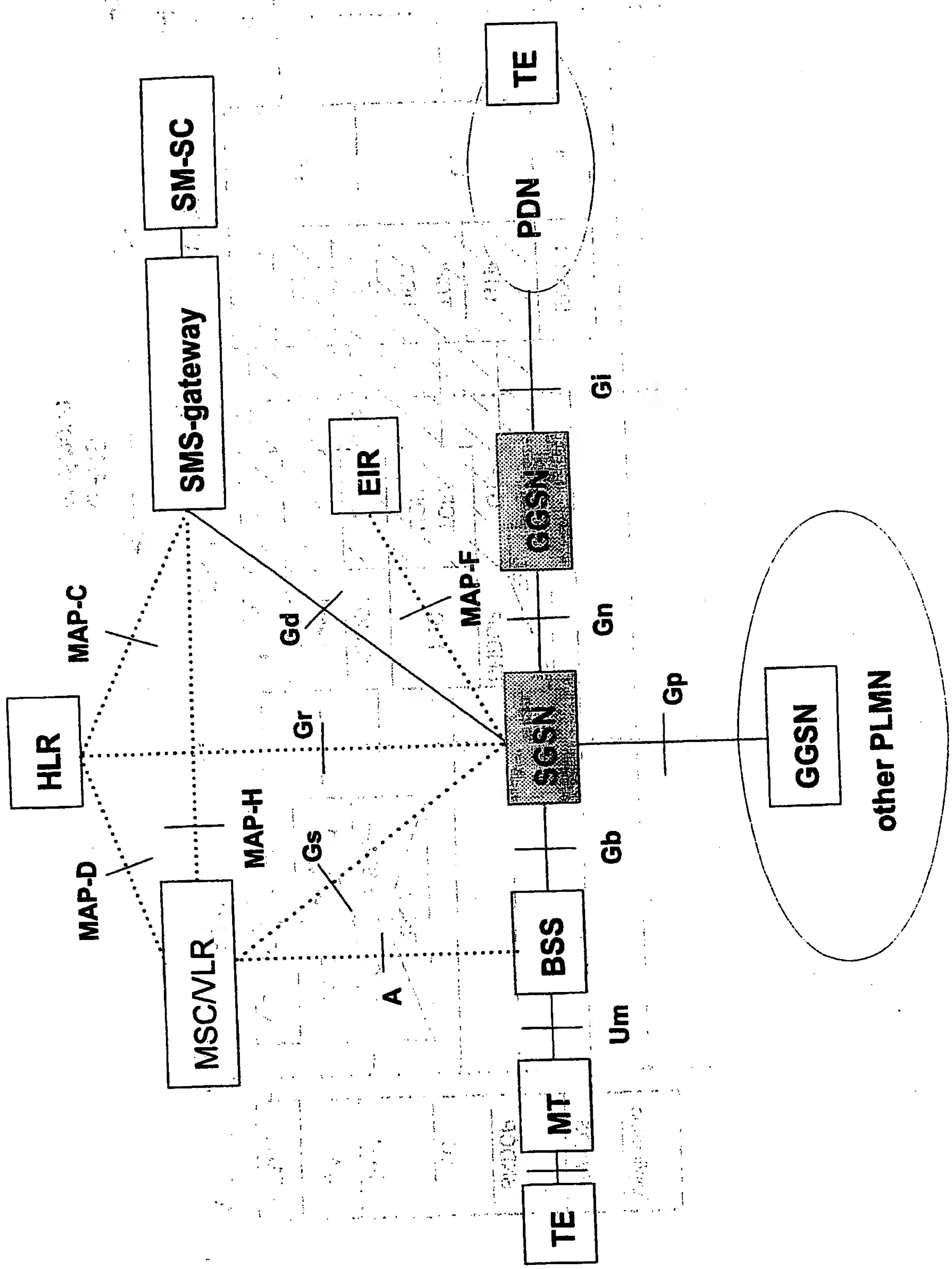
EIR
MAP-F
AUC
BSC
Abis
BTS
BSS

FIGURE 1



HLR
MSC/VLR
SMS-gateway
SM-SC
EIR
SGSN
GGSN
PDN
TE
BSS
MT
TE
GGSN
other PLMN
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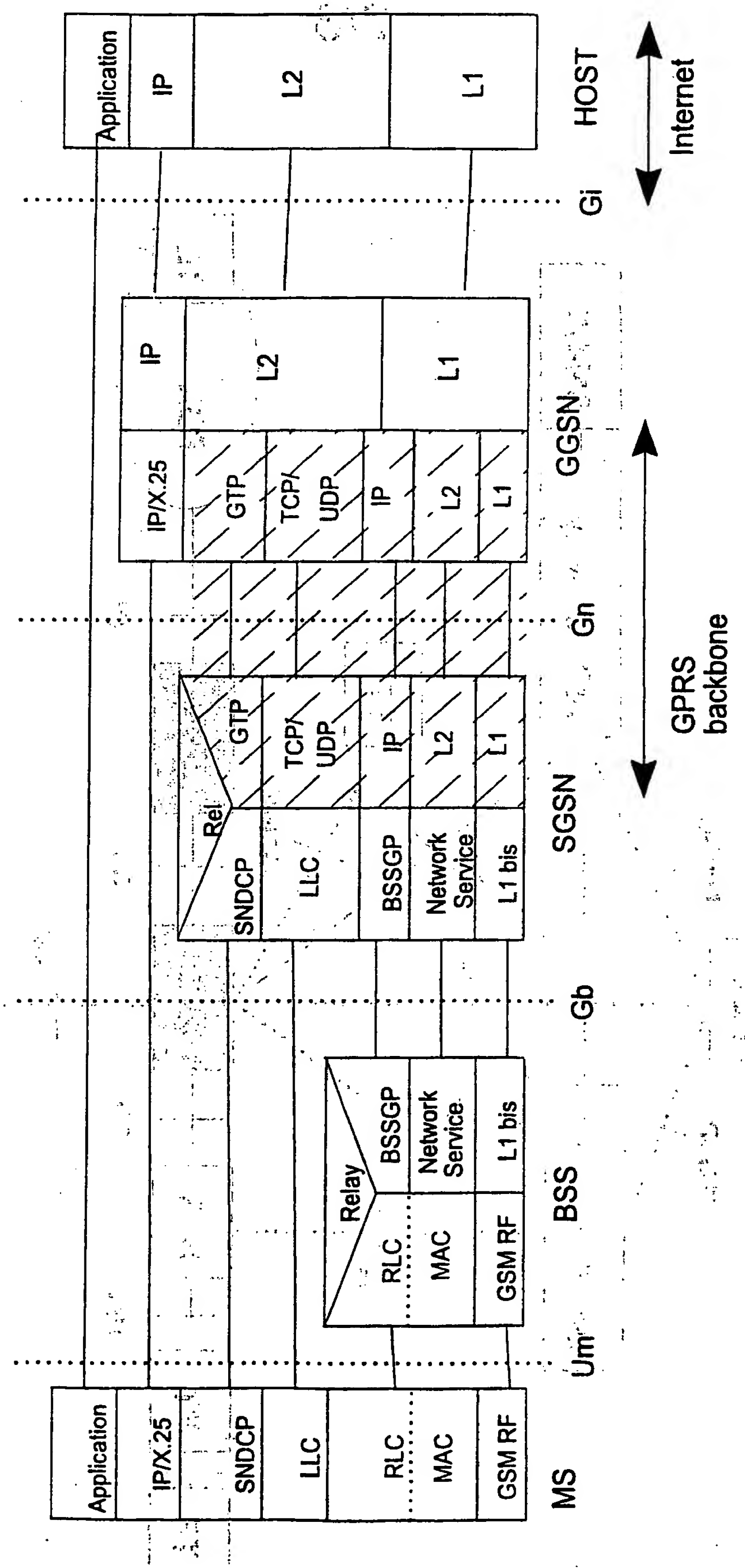
FIGURE 2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GTP
TCP/
UDP
IP
L2
L1
SNDCP
LLC
BSSGP
Network
Service
L1 bis
SGSN
Gb
Relay
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Network
Service
L1 bis
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MAC
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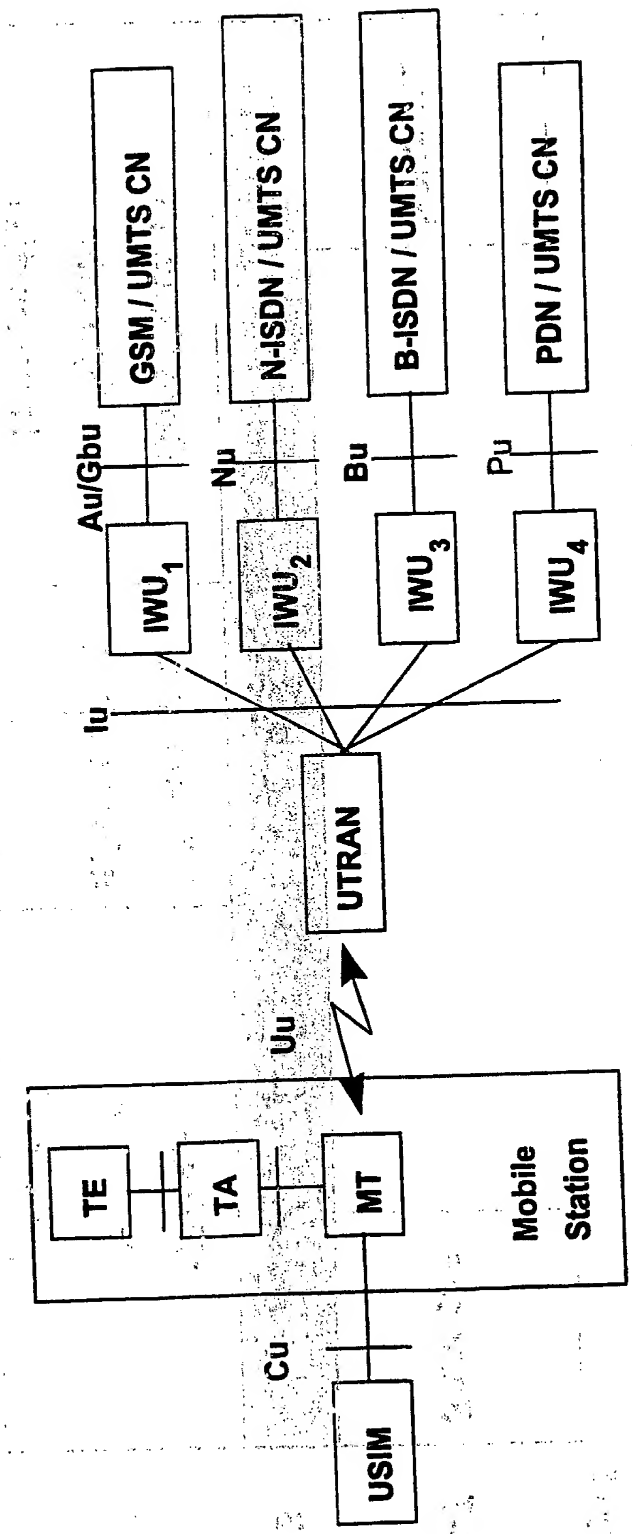
FIGURE 3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Mobile Station
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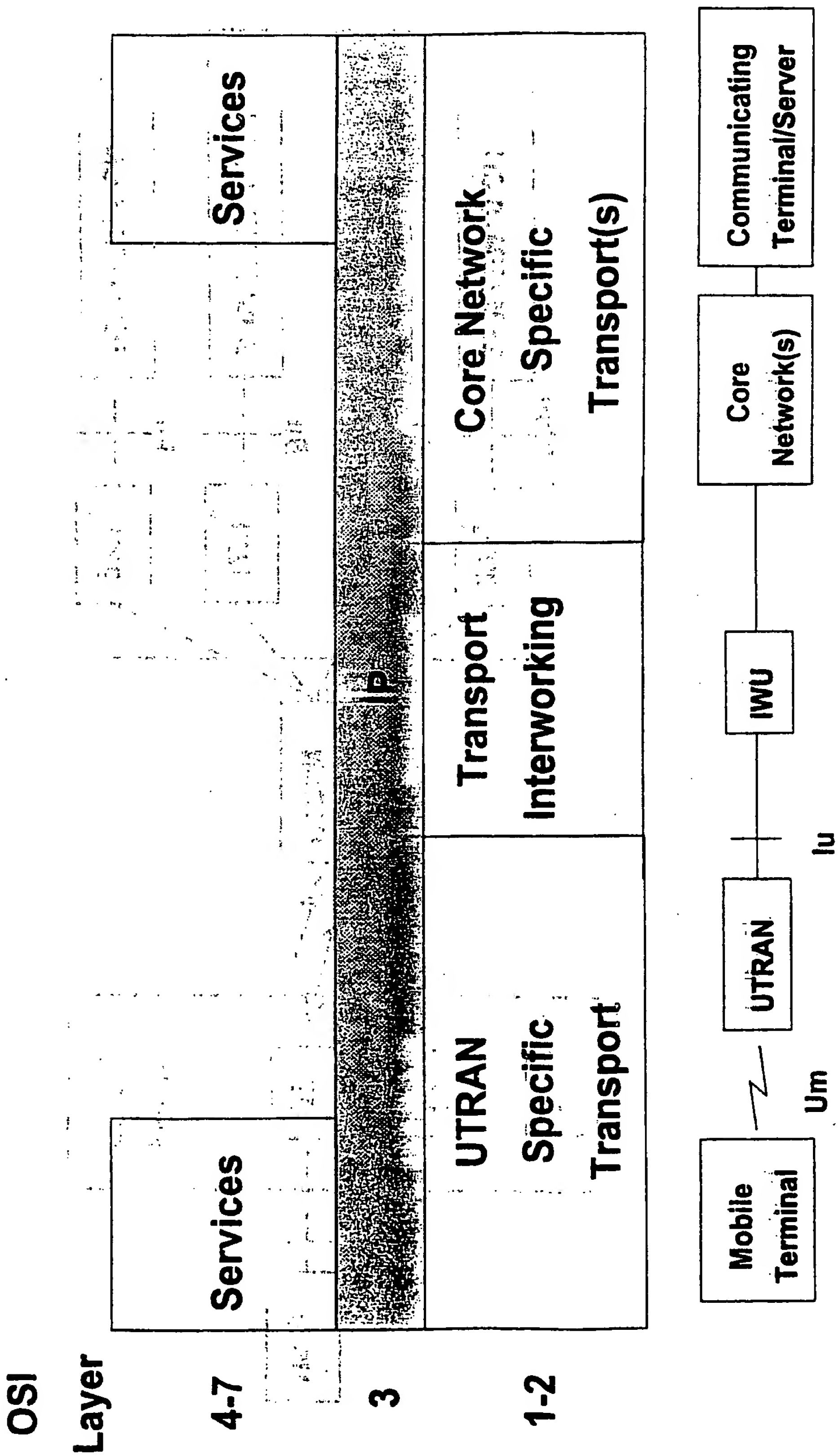
USIM

FIGURE 4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3
1-2
Services
IP
UTRAN Specific Transport
Transport Interworking
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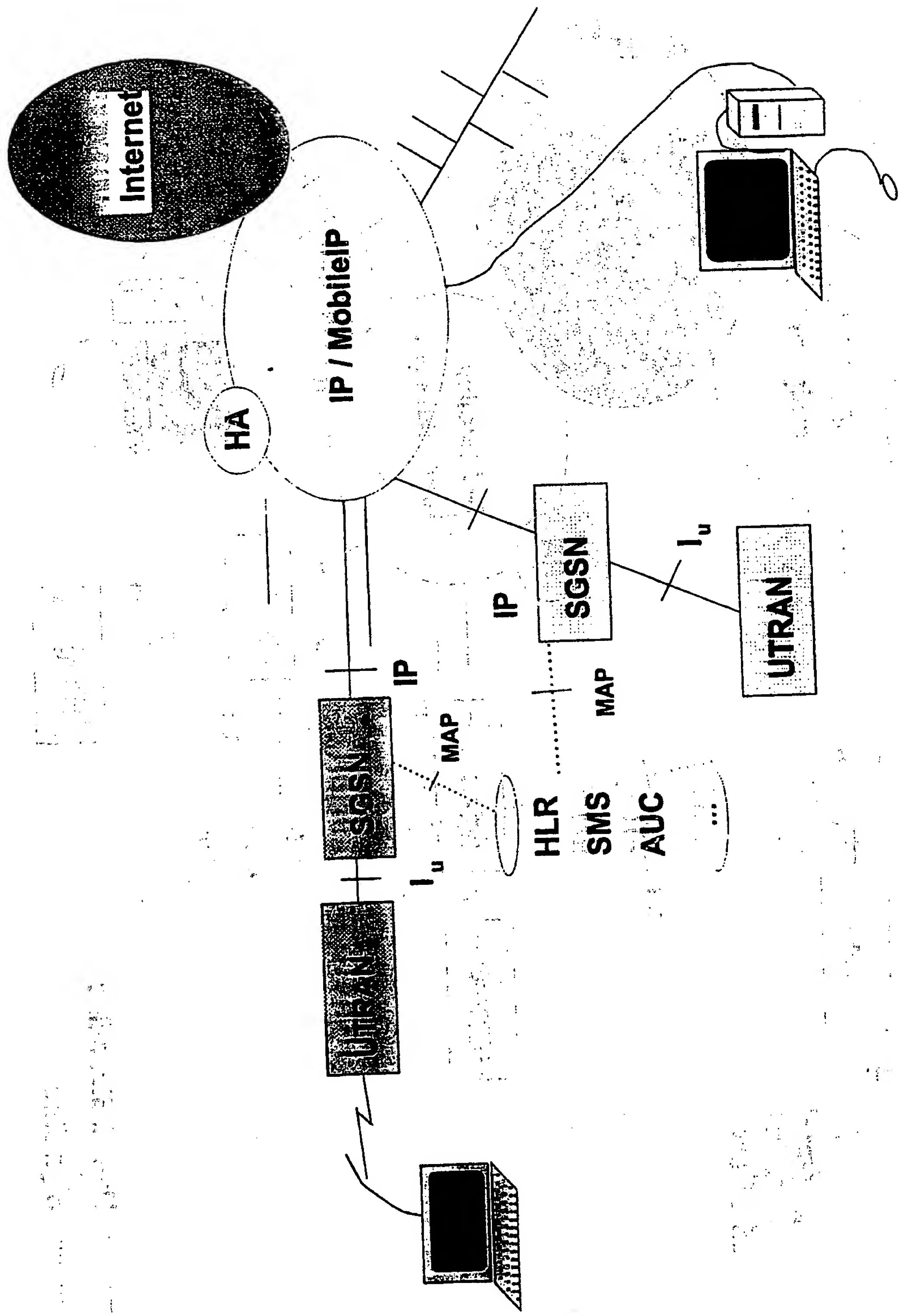
Core Network(s)
Communicating Terminal/Server

FIGURE 5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SMS
AUC
...
Data & Signalling
Signaling

FIGURE 6

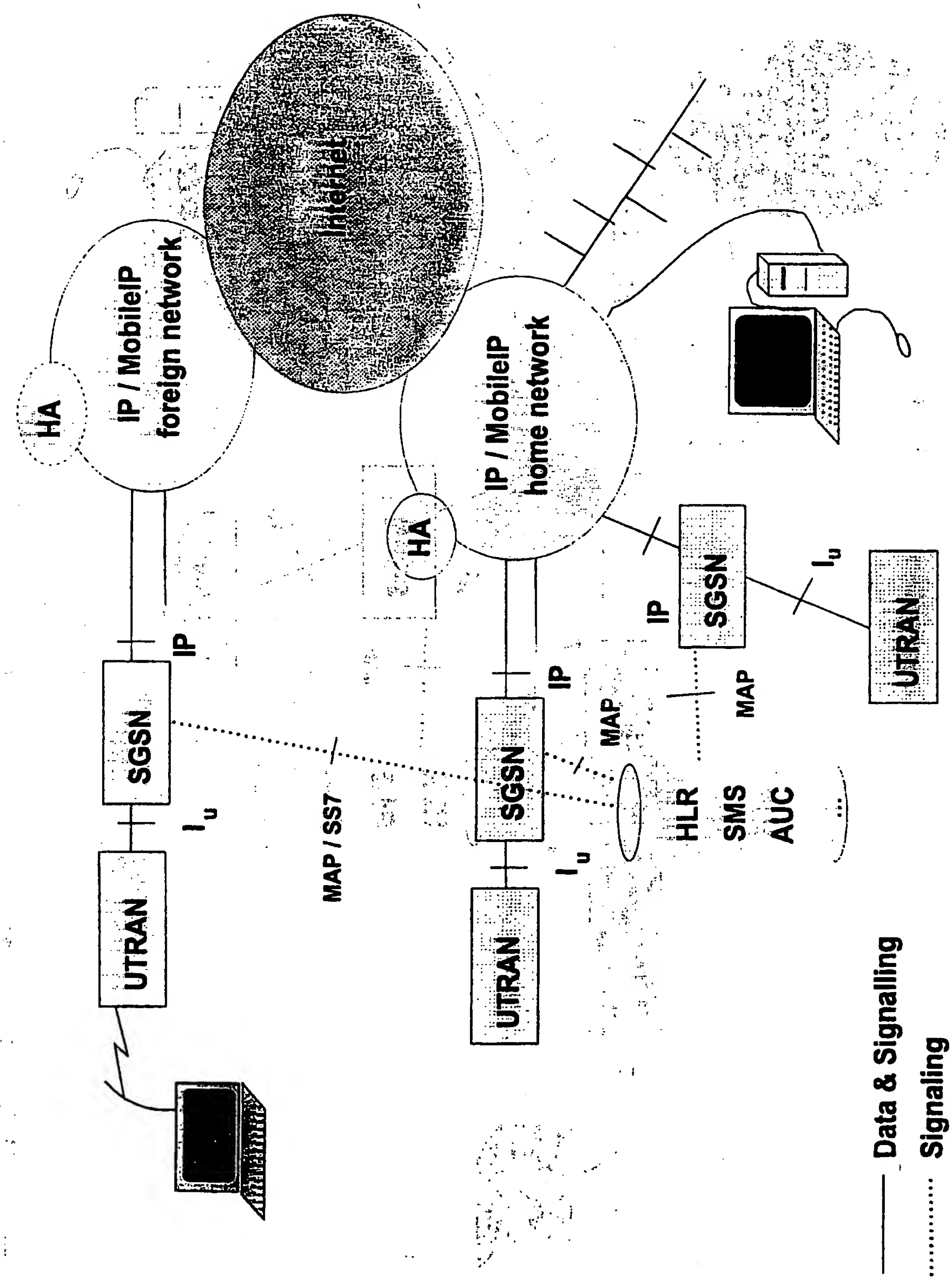
Internet
IP / MobileIP
foreign network
HA
IP / MobileIP
home network
HA
IP
SGSN
UTRAN
MAP / SS7
IP
SGSN
UTRAN
MAP
HLR
SMS
AUC
...
IP
SGSN
MAP
UTRAN
Data & Signalling
Signaling

FIGURE 7

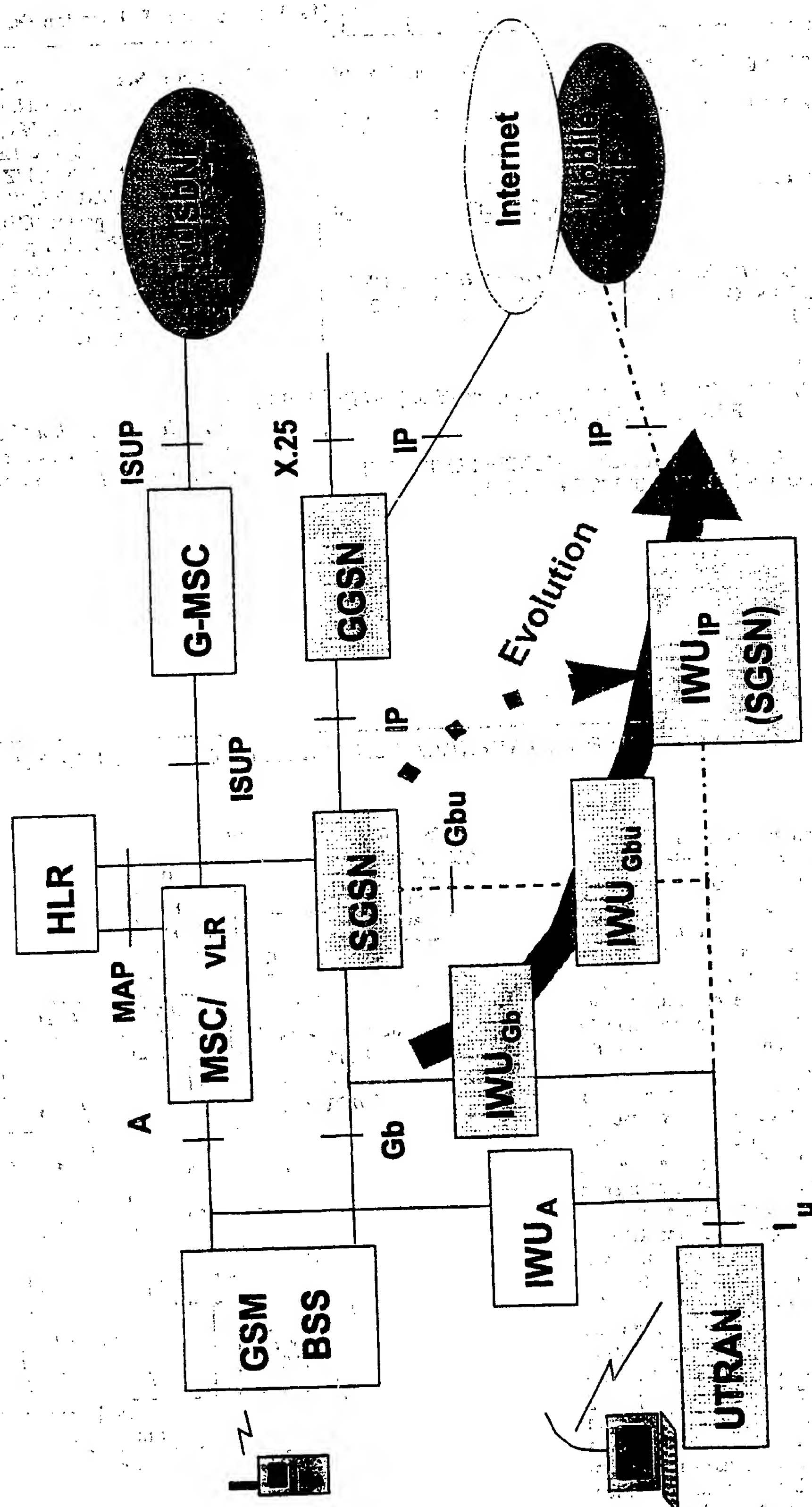
HLR
MAP
MSC/ VLR
A
GSM BSS
ISUP
G-MSC
ISUP
X.25
GGSN
IP
SGSN
IP
Gbu
Gb
IWU$_{Gb}$
IWU$_{Gbu}$
IWU$_{IP}$ (SGSN)
IWU$_A$
Evolution
Internet
IP
I$_u$
UTRAN

FIGURE 8